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Assessment of 1,1,1-TCA Degradation using Stable Carbon Isotope Fractionation

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Background. 1,1,1-trichloroethane (1,1,1-TCA) has been widely used as a solvent for metal, plastic and fabric degreasing. This has led to severe subsurface contamination. Chlorinated ethanes can be degraded by different pathways depending on the conditions. Biotic sequential reductive dechlorination of 1,1,1-TCA yields 1,1-dichloroethane (1,1-DCA) and chloroethane (CA). 1,1,1-TCA may also be degraded abiotically either by dehydrochlorination to 1,1-DCE or by hydrolysis to acetate, and abiotic degradation of 1,1,1-TCA has also been observed to be caused by FeS formed as a result of iron and sulfate reduction. Isotope fractionation during biodegradation of 1,1,1-TCA by a mixed culture have in one study been observed to be low compared to the fractionations during abiotic degradation. However, there has been little focus on carbon isotope fractionation for 1,1,1-TCA.

Objectives. The main objective of this study was to evaluate the fate and treatability of 1,1,1-TCA by enhanced reductive dechlorination in clayey till deposits with use of isotopic fractionation. The presentation will focus on the insight and documentation obtained by the use of stable carbon isotope ratios.

Activities. The investigations have included field sampling at a contaminated site for content and stable isotope ratios of the chlorinated solvents and their metabolites and a laboratory microcosms treatability study for enhanced reductive dechlorination of chlorinated solvents in clayey till from the field site including analysis of stable carbon isotope ratios.

Results/Lessons learned. The chlorinated ethanes at the field site were dominated by 1,1-DCA and stable isotope ratios documented degradation of 1,1,1-TCA. For all biotic microcosms, including the biotic control, all the 1,1,1-TCA was degraded. Only in bioaugmented microcosms and stimulated microcosms with low initial 1,1,1-TCA concentration (from sediment, no 1,1,1-TCA addition) was 1,1-DCA further degraded to CA.
The stable isotope ratio showed a clear enrichment in ^{13}C in all biotic microcosms but not in the abiotic control. The enrichment started without any lag-time and continued until 1,1,1-TCA concentrations decreased to below the necessary level for stable isotope analysis. This clearly documented 1,1,1-TCA degradation in all biotic microcosms but not in the abiotic control. It suggests, that the degradation is biotic or biotically mediated. No apparent increase in the biotic degradation product 1,1-DCA was observed during degradation of 1,1,1-TCA. This suggest, that the degradation pathway for 1,1,1-TCA may not be reductive dechlorination to 1,1-DCA. The degradation of 1,1,1-TCA occurs under iron and sulfate reducing conditions likely resulting in biotic FeS formation in the biotic microcosms. FeS can reductively degrade 1,1,1-TCA abiotically, hence the biotic formation of FeS can mediate abiotic degradation of 1,1,1-TCA. Biotically mediated abiotic degradation appears to pose a possible explanation for the observed 1,1,1-TCA degradation.